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CENTRAL INTELLIGENCE AGENCY 02 REPORT [redacted] STAT

INFORMATION REPORT RESTRICTED

FOR OFFICIAL USE ONLY

COUNTRY USSR

DATE DISTR. 26 May 1948

SUBJECT Military Geology

NO. OF PAGES 11

UNCLASSIFIED

PLACE ACQUIRED [redacted]

NO. OF ENCLS. (LISTED BELOW) 2641.1F

1954 my/FOD

DATE OF INFORMATION [redacted]

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SUPPLEMENT TO REPORT NO.

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MILITARY GEOLOGY

Chapter 4. IMPORTANCE OF MINERAL MATERIALS IN MILITARY ENGINEERING

[The term "gornaya poroda" or "poroda," generally "rock" or "stratum," is hereinafter translated as "mineral materials (s)" or "material (s)."]

I. ENGINEERING-GEOLOGICAL CHARACTERISTICS OF MINERAL MATERIALS

These materials, with which engineering officers are certain to be concerned, are primarily important in field construction as readily available construction materials. This term (gornyye porody) is generally applied to various types of materials, including the mineral materials which are used in defense constructions, in the construction of fortifications, landing fields, military roads, etc. The geologist must know not only the building properties of these materials but also their specific application, the distribution of the deposits, and special methods for prospecting, surveying, and for processing them, which are dictated by the time and circumstances of war.

Often, however, the geologist must make a many-sided approach to the study of mineral materials and must not only make deductions concerning the possibility of their use as construction materials but must also appraise them as a basis and means for military-engineering works and construction.

The great variety of mineral materials and their practical characteristics oblige the military geologist to make an accounting of their outstanding characteristics, as follows:

1. Basic nature: processability, durability, resistance to frost, temporary resistance to pressure, solidity, load-carrying capacity, firmness in declivities, etc.

2. Relationship to water: water permeability, moisture capacity, solubility, susceptibility to erosion, etc.

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3. Basic physical nature: electrical resistance, conductivity of seismic and sound waves, etc.

4. Relationship to gases (poisonous): gas permeability, capacity to absorb war gas.

Various existing practical classifications of mineral materials attempt to take into account several or most of the characteristics indicated. Among these is the classification proposed by F. P. Savarenskiy, M. M. Protod'yakonov, V. A. Priklonskiy, P. M. Tsimbarevich, L. N. Bernatskiy, and others. The military geologist may use a simplified, engineering-geological classification of mineral materials (see Table 1).

In constructing Table 1, all materials were basically divided into three groups, differing from each other in the nature of their internal cohesion (V. A. Priklonskiy). This classification imparts to them one of the following basic properties: hardness (resilience, solidity), plasticity, or porosity (friability). Corresponding to this classification is the one, widely accepted among builders, which divides all natural mineral construction materials into three categories: solid, friable, and earthen.

As V. A. Priklonskiy points out, these three groups of materials often differ from each other both in mechanical cohesive strength and also by the nature of the typical deformations in them, which gives, correspondingly, "skol," [cleavage?], plastic displacement, or displacement of friable material.

They are also characterized by the resistance of the material as a whole to weathering and the softening activity of water. Apart from the characteristics mentioned, V. A. Priklonskiy bases his classification on others -- the origin of the materials, their composition, their texture, etc.

Conforming very well with the classification indicated above, there is another characteristic, important for engineering considerations, which was originally brought out by A. P. Pavlov and later by L. N. Bernatskiy. They based their classification on the material's susceptibility to crumbling and its compressibility. Properly speaking, the classification of V. A. Priklonskiy is a further development of the classification of A. P. Pavlov and L. N. Bernatskiy. From this point of view, hard and crumbly materials are practically incompressible, but plastic materials are compressible.

In the various calculations involved in the construction of fortifications and in underground mine operations, the so-called "coefficient of stratum strength of material," "f," which comes into various reckoning formulas, is often encountered. This coefficient was established by M. M. Protod'yakonov on the basis of the various characteristics of the material, which condition the degree of difficulty in extracting and processing them. This coefficient was introduced by Protod'yakonov into his classification. In view of the wide use of this coefficient in practical operations and in calculations, it must undoubtedly be included in our schematic classification.

The table also gives the characteristics of certain groups of materials from the point of view of their physical and building properties. This material is borrowed from the resume of F. P. Savarenskiy and other sources. The variety of materials determines the range of construction qualities of the various natural materials. Along with materials of high quality, others are encountered with little or no suitability.

All varieties of construction materials, which will necessarily be dealt with in military-engineering construction are compiled in Table 1.

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Table 1. Simplified Engineering-Geological Classification of Mineral Materials

	Group	General Character of Ground	Degree of Strength of Materials	Materials
Incompressible or slightly compressible; Hard	I	Internal cohesion (Vnutrenniye svyazi) firm, hard, predominantly crystallized. Firmness (prochnost'): high to medium.	Strongest	Strongest, hardest quartz and basalt. Exceptionally strong other materials.
		Tenacity (svyaznost'): irreversible (neobpatimaya).	Very strong	Granite, quartz-porphyry silicon shales, quartzites, strongest sandy limestones.
		Incompressible		
		Water and gas permeability, only in fissures.	Strong	Very strong sandstones and limestones. Strong conglomerate. Hard granite marble and dolomite.
		Characteristic deformation: "skol", little or no moisture capacity.		
		Hard rock and semirock materials: igneous (izverzhennyye), metamorphic and sedimentary	Fairly strong	Sandstone, sandy shales and schistous sandstone.
			Medium	Clayey shales, weak sandstones, limestones, soft conglomerates. hard marl.
			Fairly soft	Soft shales, limestones, chalk, rock salt, gypsum, frozen ground marl, cemented rubble.
Crumbly	II	Internal cohesion practically nil. Crumbly, friable materials.	Fairly soft	Deteriorated rubble and gravel, gravelly earth.
		Firmness of materials, medium; depends upon composition.	Crumbly	Sands, rock waste, small gravel, filled-in soil (nacypnaya zemlya)
		Contains little or no colloids. Movement of particles on deformation takes place as in friable material. Friction high.	Running (plyvuchiye)	Running, swampy ground, thin, diluted soils. (f = 0.1-0.3)
		Characteristic deformation: displacement of friable material. Water- and gas-permeable. Material crumbly, friable, mainly products of physical weathering.		

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Table 1 (contd)

Strength Coefficient of Materials f	Volumetric Weight (gr/sq cm)	Angle of Internal Friction φ	Temporary Resistance to Compression (kg/sq cm) and Porosity (%)	Load Capacity (kg/sq cm)	Characteristics Basic
20	2.9	87°			Requires use of explosives in extraction. Vertical sides in excavations. Seismic wave speed; 2,000 - 7,000 m/sec Resistance to electricity: 10^{6}-10^{11} ohm/cm.
15	2.6	85°	Over 900 kg/cm²	15-40 and over	
10-8	2.6-2.7	82°30' 80°			
5-6	2.4-2.5	75° 72°30'	50-500 kg/cm²	5-15	Extraction requires pick, crowbar, or explosives. In excavations sidewalls-straight lines; steepness depends upon degree of weathering, fracturing and strength-nearly vertical. Seismic wave speed: 2,000 - 5,000 m/sec. Resistance to electricity: 10^{6}-10^{17} ohm/cm.
3-4	2.8-2.5	70°			
2	2.4	65°			
1.5	1.8-2.0	60°	30-35%	0.5-6	Extraction mechanical and manual. In sidewalls, angle of 30-40° (angle of natural slope). Height of sidewall does not depend on angle of sidewall. Form of sidewall: rectilinear. Seismic wave speed: 800-1100 m/sec. Resistance to electricity: 10^{10} ohm/cm.
0.5-0.8	1.6-1.8	40°-37°			
0.3	1.5-1.8	9°			

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Table 1 (contd)

		Group	General Character of Ground	Degree of Strength of Materials	Materials
Compressible	Soft (earthy)	III	Cohesion elastic, pre-dominantly colloidal and aqueous. Firmness not great; sinks, depending on degree of moistening, to nil. Cohesion reversible. Little or no water/gas permeability.	Soft	Thick clay. Clayey soils.
			Characteristic deformation: plastic displacement. Friction low. Plastic, soft materials: cohesive soils.	Soft	Light sandy clay, loess.

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Table 1 (contd)

Strength Coefficient of Materials	Volumetric Weight (gr/cm^3)	Angle of Internal Friction φ	Temporary Resistance to Compression (kg/cm^2) and Porosity (%)	Load Capacity (kg/cm^2)	Basic Characteristics
1.0-(1.5)	1.8	45°	40-55% (porosity in dry state)	0.5-6	Extraction mechanical and manual. Steepness and height of sidewalls depends upon strength of cohesion (moistness) and friction. Form of sidewalls: concave curve.
0.8 and less	1.6	40°			In dry state clayey soils and loess have vertical sidewalls. Seismic wave speed: 1300-1700 m/sec. Resistance to electricity depends upon porosity, moistness and presence of salts. Dry and crumbled clay impervious to poison gas. Black earth permits passage of poison gas, but many gases unite with particles of humus and are absorbed. Can be used as peat. Peat absorbs many poisonous gases. Can be used as filter.

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II. MINERAL CONSTRUCTION MATERIALS

Mineral construction materials can be divided into natural and artificial. The former are the extremely varied natural mineral materials which are used in construction; the latter, the same, with a definite technological processing.

A. Natural Mineral Construction Materials

To this group belong all materials, varied in their properties, origins, and outward appearances, which lie at hand near the sites of fortification construction and military-engineering installations. Construction materials which must be transported to the site can be used only in the construction of rear, defense lines.

Solid mineral construction materials, so-called "construction stones," are almost always used in crude form due to extreme limitations of time available for construction of field installations. Either coarse blocks, boulders, or rubble (course chunks of uneven form), or cobblestones (small boulders), are used. A finer processing of construction stone by means of cutting off and trimming into separate blocks of various dimensions is used only when there is sufficient time, mainly under conditions of a stabilized front or in a rear, defense zone.

According to the importance and the period of service expected, there are various requirements for solid construction materials; these requirements are determined by the type of work for which the construction stone is to be used.

For example, material intended for road surfaces must be tough or sufficiently resistant to breaking up, hard or sufficiently resistant to wear; must possess sufficiently high resistance to compression; and must be frost-resistant, etc.

Material used for hydrotechnical constructions must have a high volumetric weight, low porosity, negligible solubility, low water-permeability, frost-resistance, sufficient resistance to compression, general hardness and firmness.

Construction stone used for foundations, for the "teeth" (zuby) and "mattresses" (tyufyaki) of earth and timber pillboxes (dzot) must be highly resistant to compression, frost-resistant, solid, durable from the point of view of solubility, etc.

Coarse blocks are used in the construction of hydrotechnical installations (for ports, for example) and in the construction of antitank barriers in the form of stone road-blocks, etc. Wide use is made of rubble in the stone work of supporting walls, in bridge building, sometimes in railroad embankments, for filling in the spaces between pillbox walls, for the "teeth" and "mattresses" of pillboxes, for the coverings of trench constructions in the so-called "hard layer," and sometimes as an addition to concrete as an inert component. Rubble is often used as road material. Rubble, derived from various kinds of rock is used for all these purposes. For these, stones from large-crystal (massivo-kristallicheskiye) rock are considered superior. Of these, the fine-crystal variety with great temporary resistance to compression, are the more highly prized for purposes of construction; the coarse crystal variety (especially granites), which yield easily to weathering processes, are considered less desirable. Strongly cemented sandstones [presumably natural cementation] of sufficient strength and firmness are widely used; weakly cemented sandstones are especially unsuitable for fortification construction.

In the absence of the materials indicated, carbonaceous varieties of stone -- limestones, dolomites, marls -- are used. The hard, fine - grained varieties of these are considered the best. Porous limestone is considered the worst for building purposes. Carbonaceous rocks are also used as raw material in the preparation of cement. Limestone with $Ca\ CO_3$ content of 75-80 percent is considered good.

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Rubble, deriving chiefly from large-crystal and metamorphic rock is no less widely used. Petrographically, these rocks are extremely varied. Thus, for example, in one cubic meter of boulders from the Moscow region, more than 60 diverse types of rock were counted. Rubble is used as road material, for filling in the space between the walls of pillboxes, for the "teeth" and "mattresses" of pillboxes, for the "hard layer" of trench constructions, etc. Coarse boulders are sometimes used in construction in place of ordinary construction rubble; sometimes they are processed block rubble.

Crumbly mineral construction materials -- sand, gravel, and small rubble -- are among the natural construction materials, widely used in various fields of military engineering.

Sands in nature of various mineral compositions "polimiktovyye" and "oligo-miktovyye" and of various sizes of grains are found. At the same time those sands have various constructional values and various spheres of use.

Gravel and small rubble also have various mineral compositions and include crumbly, fragmentary rock, whose particles have a diameter of 2.5 to 5 mm and up to 100 mm. Small rubble may be either natural, in the form of rock waste, gravel, etc., or produced artificially by means of crushing.

Sand, like gravel and small rubble, is among the most widespread of construction materials and is used as an inert ingredient in concrete, for filtering and drainage, as ballast material, as a filler in roadbeds and as the foundation for roads. Moreover, it finds use as an ingredient of cement mortar and for the base (nastil) of the material for dams and dikes.

The best sands for use as fillers in the preparation of concrete are the coarse- and medium-coarse-grain, and those with a mixed grain.

Mica, sulfur pyrite, and gypsum are injurious admixtures in sands. Mica weakens the cohesion of cement mortar, and its content should not exceed one percent. The decomposition of sulfur pyrite and gypsum produce a chemical reaction in the concrete whereby Deval salts are formed, which, as the result of union with water, increase the volume 2.5 times and destroy the concrete. When pyrites and gypsum are encountered, it is recommended that the SO_4 content of the sand be determined; the SO_4 content must be less than 0.3 percent.

Furthermore, sand used for concrete must be pure and must not contain clay or dust particles (of dimension less than 0.05 mm). According to existing standards, such particles should not exceed 5 percent of the weight of the sand. In such a case, clayey particles (less than 0.005 mm in diameter) should compose not more than 2 percent.

Especially undesirable is the admixture of clay which coats the grains of sand since that impedes the consolidation of the sand by the cement and also lowers the firmness of the concrete.

Organic admixtures in the sand (humus, etc.) are very harmful to concrete; they seriously reduce its firmness.

Gravel and small rubble for making concrete should also have the characteristics indicated for sand. The size from 2 to 80 mm is considered the best. Machine-made gravel should have sufficient firmness (not less than 900 kg/sq cm).

Coarse-grain sands are considered the best variety for road construction. These sands, which are packed in the foundation of the roadbed for uniform distribution of load-weight on the ground and to prevent soaking of the road and accumulation of water under road covering should not contain over 10 percent of dusty or clayey particles (smaller than 0.05 mm) or more than 3-5 percent of clay particles (0.005 mm) alone.

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Coarse-grain sands and gravel with rubble are used for railroad ballast. They resist washing out or being blown by the wind, they produce little dust, and they cause few gaps when frozen.

Sands used for filler in small dams and dikes having tactical importance should be of varied grain and sufficiently clayey.

Sands, gravel, and rubble, used for drainage must be but slightly susceptible to weathering and of a definite hardness. Material used for filtering must be of uniform grain (small sand is best) and devoid of clayey particles and organic admixtures.

Earthy mineral construction materials consist of the various clays, clayey soils, peat, and sod.

Surface soils with soil layers containing vegetable matter of various mechanical composition, are also included under "earthy material." Such ground is used in sacks for bank revetments to protect them from slipping; trenches are covered with it, too. Sod, which is the top layer of vegetational soil covered with grass and overgrown with roots and possessing a fair amount of firmness, is no less widely used. It is used in the erection of military-engineering constructions, as revetment for slopes, as camouflage for various constructions of false emplacements, trenches, etc.

The earthy layer is also used as auxiliary camouflage coloring material. For example, dried and sifted black earth with a waterfixing agent, can be used as a gray-brown color; with a tarry fix or with drying oil it gives a dark brown color.

Colored clay, which is found in nature in various hues and shades, can also be used for this purpose. The required tone can be had by means of mixtures. It is the geologist's duty to exploit this unusual material in the region of troop disposition.

Clays are used in the construction of various military-engineering installations, and a variety of demands is made on them for various purposes. Thus, for the locks, screens (ekran), and front parts of the spillways (ponur) of dams, very oily clays are recommended, but for the embankments of dams (in extraordinary cases) clay with a high sand content (50 percent and more) should be used.

Oily clay is used as water-shedding material in covering of earth and timber pillboxes, reinforced-concrete pillboxes (DOT), and other constructions.

Finally, clay is used in the preparation of bricks. Clay with a sand content of 30 percent, devoid of lime concretions, is considered the best.

B. Artificial Mineral Construction Materials

This group included the various natural mineral construction materials which are subjected to technological processing, particularly various types of bricks: adobe, sun-dried bricks, burnt bricks in the form of construction bricks and clinker bricks. Also included among these are various fixing agents which are used for cementing soils. The technology of the production of these materials and various new fixing agents are described in specialized literature, which is fairly well-known, and we shall not discuss them here.

Concrete, the most important construction material of the group under consideration, owes its great worth to the fact that it is almost entirely composed of locally available materials; cement, the ingredient which must be brought from elsewhere, amounts, at most, to 10-12 percent by weight.

In all concrete, the following elements must be distinguished: the active ingredient -- the binding material made of cement and water, whose interaction produces cohesion and solidification; the inert ingredient -- sand, gravel, rubble, slag, etc. Between the cement [literally, cement stone] and the inert (or filler) component, only a mechanical cohesion exists. The inert component amounts to 60-80 percent of the total volume of concrete.

The advantage of concrete lies in the fact that a great variety of properties can be given to it at will: its density, volumetric weight, and solidity can be controlled. This is achieved by the selection of its ingredients, by taking account of its composition, and by exercising care in the preparation and laying of the concrete mixture. Among the many kinds of concrete, the heavy (with heavy filler) and especially dense (plotnyy) (0.8-0.9) kind is used for fortification construction.

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The requirements for the filler have been indicated above. We add only that the sand must be of varied coarseness in order to avoid a great consumption of cement. Therefore, it is useful to determine the porosity of the sands, which must not exceed 37 percent. Furthermore, unsuitable granular texture of the filler may be reflected in the solidity of the concrete.

Cements, as is known, are divided into two major groups: air cement and hydraulic cement. [There follows, general, elementary data on the properties of cement, methods of its preparation, and instances of the use of cement and reinforced concrete prior to and during World War I, which has been omitted.]

C. Secondary, Readily Available Mineral Construction Materials

Secondary, readily available construction materials include all those materials, or things made from them, which lie at hand during the construction of a fortification. These materials may be most varied -- mineral, vegetable, etc.

Slag, which is widely distributed in certain regions, can be used, for example, as an inert ingredient in cement. In the absence of stone construction material, gravestones can be found in cemeteries, stony material in garden walls and house foundations, etc. All this can be used in the erection of military-engineering constructions.

In many cases, brick rubble, cracked bricks, can be found in abundance. When materials for concrete are lacking, brick rubble can be used in extreme cases as filler.

Red brick, crushed, ground, and sifted as a powder, can be used with any fixing agent as red paint for purposes of camouflage. Road dust can be used to make a dark, earth color. Black color is produced by crushing and grinding charcoal to a powder; the necessary shade can be obtained by mixing this with other coloring matter, such as colored clays. Mixing with yellow clay produces a color approximating khaki; mixing with chalk produces a color approximating khaki; mixing with chalk produces a gray.

In the practical work of constructing the various fortifications, the geologist must deal with other types of construction materials, wooden and iron. He must get his introduction to these in specialized literature on the subject.

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